



Water insecurity and lived experiences in Nairobi, Kenya: a comparative mixed-methods study of informal and formal settlements through the lens of the Human Right to Water

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ABSTRACT

Access to safe drinking water, sanitation, and hygiene (WASH) remains a major global challenge, disproportionately affecting residents of informal settlements, where insecure tenure, unsafe housing, limited WASH access, and socio-economic marginalisation exacerbate water insecurity, undermining health and well-being.

Our comparative mixed-methods study assesses water insecurity, lived experiences, coping strategies, and community recommendations in informal and formal settlements of Nairobi, Kenya, through the Human Right to Water (HRTW) – considering availability, accessibility, quality, safety, affordability, and acceptability. Integrating focus group narratives with survey data, this is the first study to compare HRTW realisation across settlement type, gender, and age.

The HRTW remains unrealised across settlement types, with frequent interruptions, unreliable supply, uneven access, long collection times, high costs, and poor water quality, especially after service disruptions and during the rainy season. Conflicts over water access are widespread, undermining trust, and deepening social and gendered stress. Water collection causes illness, emotional strain, and fatigue across settlements. Water insecurity is deeply gendered. Women, particularly in informal settlements, bear the greatest burden regarding time, safety risks, physical and emotional strain, whereas age differences are less pronounced. Residents adopt diverse coping strategies, yet those in informal settlements are more constrained by limited storage and financial capacities, relying on social networks. Our findings show that residents across settlements navigate water insecurity through hybrid, negotiated strategies, challenging the formal-informal dichotomy.

Addressing water insecurity requires integrated, participatory approaches, with active community engagement to co-develop gender-inclusive, context-specific solutions that meet the needs of the most vulnerable.

1. Introduction

Access to safe drinking water, sanitation and hygiene (WASH) remains a major global concern. Worldwide, one in four people still lack access to safe drinking water, and two out of five people do not have access to safe sanitation (UNICEF and WHO, 2025). Ensuring water security – providing water of good enough quality and quantity – is essential not only for preventing diseases, but also for supporting mental health, psychosocial well-being, and overall quality of life (Kangmennaang and Elliott, 2021; Winter et al., 2019).

Water insecurity disproportionately affects low-income and

disadvantaged populations and those living in the poorest neighbourhoods (Abdulhadi et al., 2024; Dickson-Gomez et al., 2023; Fleming et al., 2019; Rhodes-Dicker et al., 2022). In informal settlements, water insecurity both results from and reinforces poverty, reducing household income and economic development (Adams et al., 2020). Residents face overlapping vulnerabilities, including unsafe housing, inadequate infrastructure and basic services (water, sanitation, waste management, energy, transport, healthcare, education), insecure land tenure, and social and political marginalisation, all undermining health and well-being (Chumo et al., 2023; Corburn and Karanja, 2016). Limited access to reliable piped water, poor water quality, inadequate drainage,

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overcrowding, and insecure tenure heighten exposure to environmental hazards and infectious diseases, particularly during extreme weather events that disrupt WASH infrastructure and contaminate water supplies (Dominguez, 2024; Fleming et al., 2019; Howard et al., 2010; Reynaud et al., 2013; Rosinger, 2018). These conditions create reinforcing cycles of poor WASH, environmental hazards, overcrowding, and poverty (Twigg, 2015), disproportionately affecting the most vulnerable (Karuga et al., 2023).

The COVID-19 pandemic further exposed and intensified existing infrastructural and social vulnerabilities, particularly in informal settlements, where recommended hygiene measures depended on water access that was often unreliable, unevenly distributed, and unaffordable. Emergency interventions such as free water provision temporarily alleviated hardship in some areas, but were geographically uneven, temporary, and insufficient to address long-standing structural deficiencies, highlighting persistent infrastructural inequalities (Curty Pereira et al., 2023; Kasper et al., 2025; Kim et al., 2022). The pandemic also revealed how political decisions shape the distribution of social and environmental health determinants, while bottom-up civil society initiatives played a vital role in delivering emergency support and adapting public health measures to local realities (Curty Pereira et al., 2023). In Nairobi, the pandemic triggered interventions that had been feasible but long neglected, highlighting the urgent need to address enduring deficiencies and micro-level disparities to build more resilient and equitable water and WASH infrastructure (Kasper et al., 2025).

A substantial body of literature has examined water insecurity in informal settlements (Rhodes-Dicker et al., 2022) through qualitative, quantitative, spatial, and mixed-methods designs, highlighting economic, spatial, social, political, and institutional drivers and barriers to water service delivery and access in informal settlements (Pierce, 2017). Informal settlements are typically unplanned areas that develop outside official land registries, planning regulations, and legal frameworks (Satterthwaite et al., 2019; UN-Habitat, 2015), whereas formal settlements are planned and regulated spaces with legally recognised tenure and access to improved services (Chrispus and Shema, 2025). Residents of informal settlements experience poorer WASH outcomes, including fewer piped water connections, greater reliance on water vendors, more frequent service interruptions, and higher water costs (Ezeh et al., 2017; Fleming et al., 2019; Rhodes-Dicker et al., 2022). Despite well-documented disparities, settlement-specific data remain scarce (Sinharoy et al., 2019), and direct comparisons of lived water insecurity experiences across settlement types are lacking.

At the same time, urban scholarship cautions against treating formality and informality as fixed or oppositional categories. Rather, they are interdependent and often co-constitutive domains, intersecting through governance practices, infrastructural arrangements, and everyday negotiations, often producing hybrid urban service landscapes (Dovey and Kamalipour, 2017; Jenkins and Eskemose, 2011; McFarlane, 2012). This study addresses this gap by comparatively examining lived water insecurity experiences across informal and formal settlements, while critically engaging with the fluid and overlapping realities that shape these experiences.

Water insecurity is not only spatially differentiated but also socially stratified. Gender shapes relationships to water access, use, knowledge, governance, and experiences (Harris et al., 2017). In many countries, particularly in Sub-Saharan Africa, women bear primary responsibility for household water management, and connected water- and health-related practices (Dickin and Caretta, 2022; Van Houweling, 2016). This responsibility exposes them to time burdens, safety risks, physical and emotional strain, health concerns, and psychosocial stress (Adams et al., 2022; Amankwaa et al., 2024; Dominguez, 2024; Kimutai et al., 2025; Nunbogu and Elliott, 2022), whereas reliable access supports multiple domains of women's health-related quality of life (Winter et al., 2019). Women are also often excluded from water-related decision making (Adams et al., 2018). Despite longstanding calls for sex-disaggregated and gender-responsive WASH research, substantial

gender data gaps persist, limiting understanding of how water insecurity is differentially experienced and socially reproduced. Without explicitly assessing gendered impacts, interventions risk obscuring differential burdens and unintended harms (Caruso and Sinharoy, 2019; Khalid et al., 2024).

Age further shapes water insecurity experiences through differences in water- and health-related knowledge, attitudes and practices, health status, mobility, economic resources, and social roles. Older adults may face distinct vulnerabilities in accessing safe water and adopting protective practices (Crampton and Ragusa, 2016; Duan et al., 2022; Maniragaba et al., 2023). Older men may face heightened water insecurity as age amplifies the burdens of socially prescribed roles as household heads and primary earners (Khalid et al., 2024). Children, particularly girls, are disproportionately affected through health risks, school absenteeism, and safety concerns (Chumo et al., 2023; Karuga et al., 2023; Zerbo et al., 2020). Yet, analyses disaggregated by age and gender remain limited, particularly within settlement-specific contexts. By differentiating findings by settlement type, gender, and age, this study responds to calls for such disaggregated data, supporting the design of context-sensitive interventions and policies that account for the complex interplay of individual, social, and structural factors shaping water insecurity experiences (Khalid et al., 2024).

Measuring these experiences requires acknowledging that water security is a multidimensional concept, with no single consensus definition. Its four core domains include availability, accessibility, use, and reliability, encompassing further aspects such as quantity, quality, affordability, and safety (Jepson et al., 2017; Khalid et al., 2024; Young et al., 2021). UN Water (2013) frames water security as the ability of societies to ensure sustainable access to sufficient quantities of safe and acceptable water to support well-being and development, while protecting ecosystems and reducing vulnerability to water-related risks. Water security is also shaped by social and political dynamics influencing how water is governed, distributed, and used (Jepson et al., 2017). Consequently, its meaning and measurement vary across sectors, scales (from individual, household, neighbourhood to national and regional) and geographical or cultural contexts (Khalid et al., 2024), underscoring the importance of examining lived experiences across settlement types and population groups.

These dimensions overlap closely with the normative content of the Human Right to Water (HRTW), formally recognised by the United Nations General Assembly in 2010 (United Nations, 2015a) and addressed in the 2030 Agenda for Sustainable Development Goals (SDG 6) to “ensure availability and sustainable management of water and sanitation for all” (United Nations, 2015b). In Kenya, the HRTW is reinforced through the 2010 Kenya Constitution, which emphasises marginalised groups' rights to reasonable access to water (Government of Kenya, 2010). The HRTW normative criteria – availability, accessibility, quality and safety, affordability, and acceptability – alongside cross-cutting principles of equity and non-discrimination (UN Economic and Social Council, 2003), offer a lens for evaluating whether water services meet the needs of all, particularly marginalised populations.

While water insecurity research has increasingly focused on measuring lived experiences, few studies integrate these insights with a rights-based framework. The HRTW establishes internationally recognised normative criteria, whereas water insecurity research captures individual- and household-level experiences revealing how these standards are met, or not, in daily life. Integrating these approaches links legal and ethical obligations to lived experiences, illuminating where, for whom, and why water insecurity is most severe, and how it affects everyday life, health, and well-being. Applying HRTW dimensions across informal and formal settlements enables systematic comparison of availability, accessibility, quality, safety, affordability, and acceptability across population groups, enhancing both policy relevance and understanding of water insecurity's multidimensional nature.

Despite extensive research on water insecurity in informal settlements, critical knowledge gaps remain, particularly in rapidly

urbanising contexts such as Kenya (Kimutai et al., 2025). Water insecurity affects 63% of Kenyans, mainly in terms of affordability and sufficiency, with clear disparities by residence, housing type, and socio-economic status (Njoroge et al., 2024). Over half of Nairobi's population lives in informal settlements, where most households rely on costly private water providers (Joshi et al., 2023).

This study provides a comparative analysis of water insecurity in Nairobi's informal and formal settlements, identifies key drivers – including residents' perceptions of underlying causes and seasonal variability – and examines associated lived experiences and coping strategies. Unlike most studies focusing exclusively on informal settlements, it highlights disparities and commonalities in water insecurity across settlement types, shedding light on the fluidity between informality and formality. A key contribution lies in analysing how HRTW dimensions and associated lived experiences vary by settlement type, gender, and age. To our knowledge, this is the first study to integrate the HRTW framework in this disaggregated and comparative way. By combining focus group discussions with a household survey, the study integrates quantitative indicators with residents' narratives, producing holistic, context-specific insights to inform more equitable urban planning and policy.

The following research questions will be addressed:

1. Has the Human Right to Water been realised in informal and formal settlements in Nairobi, Kenya, and how do experiences vary by settlement type, gender, and age?
2. How do lived water insecurity experiences compare across informal and formal settlements?
3. How do residents cope with water insecurity in informal and formal settlements?
4. What are the perceived underlying causes and challenges driving water insecurity and service interruptions in informal and formal settlements?

2. Methodology

2.1. Study sites: informal versus formal settlements in Nairobi, Kenya

This study was carried out in contrasting settlements in Nairobi, Kenya. The formal settlements included Jericho Lumumba and Harambee estates in Harambee ward, Makadara Sub-County. The informal settlements comprised three villages (Grogan A, Korogocho B, and Kisumu Ndogo) in Korogocho ward in Ruaraka sub-County (Fig. 1). Jericho Lumumba and Harambee are planned residential estates and therefore provide an appropriate comparison with the largely residential but unplanned settlements in Korogocho. High-income formal neighbourhoods in Nairobi (e.g. Parklands or Westlands) were not selected



Fig. 1. Map and visual characterisation of the study area: Formal and informal settlements in Nairobi, Kenya.

because their high-rise buildings, mixed commercial-residential land use, and substantially higher income levels would introduce structural differences beyond the formal–informal distinction central to this study. The selected sites differ in spatial layouts and infrastructure provision. Although both settlement types receive piped water from the Nairobi City Water and Sewerage Company (NCWSC), they differ in access to safe water, sanitation facilities, and drainage, as well as in flooding exposure and vulnerability. In addition, the African Population and Health Research Center (APHRC) has previously worked in these communities, which facilitated community entry and helped build trust, particularly on sensitive topics, such as lived experiences of accessing water.

Jericho and Harambee estates are predominantly middle-class neighbourhoods, spatially planned by the Nairobi City County Government. Residents generally experience better health and greater access to quality services than those in informal settlements (Ochako et al., 2016). APHRC conducted transect walks to better understand housing conditions, WASH infrastructure, and the state of formality in the different estates. Homeownership is common, housing infrastructure well developed and planned, and households have access to piped water from the NCWSC distribution network and are connected to the sewer system. Alternative water sources include privately operated boreholes or rainwater, commonly stored in large water tanks. The presence of functional sanitation and sewer systems substantially reduces the risk of contaminated drinking water and related infectious disease exposure (Fig. 1).

Korogocho is among the most densely populated areas in Nairobi and is characterised by informal housing, underdeveloped infrastructure (Beguy et al., 2015), and chronic poverty (Wamukoya et al., 2020). Korogocho has long been associated with some of the worst health and socio-economic conditions among Nairobi's informal settlements (APHRC, 2002). Access to essential services such as piped drinking water, sanitation, and electricity is limited and unreliable (Chumo et al., 2022). Most households depend on buying water from vendors or kiosks for drinking and other needs. Alternative drinking water sources include boreholes operated by private or community-based providers, often supplying water through kiosks with overhead storage tanks. Due to the limited access to sewer systems, most residents rely on pit latrines, usually shared among multiple households (Tomoi et al., 2025) (Fig. 1). During Kenya's recent long rains, parts of Korogocho experienced severe flooding (Kimuyu, 2024), exacerbating existing water and sanitation challenges.

In this manuscript, we refer to Jericho Lumumba and Harambee as formal

settlements, and Korogocho as informal settlements.

2.2. Study design

We adopted a mixed-method, comparative cross-sectional study design in informal and formal settlements, employing focus group discussions and a household survey, to assess water insecurity, including drinking water availability, accessibility, quality, safety, affordability, and acceptability, as well as residents' lived experiences, coping strategies, and community recommendations, through the lens of the HRTW. Ethical clearance for this study was received from the Ethics Review Board at the Faculty of Geo-Information Science and Earth Observation at the University of Twente (#240,656; approval date: 20.09.2024) and from the Ethics Scientific Review Committee at AMREF Health Africa (approval number ESRC P1713/2024, approval date 30.09.2024). A research permit was obtained from the National Commission for Science, Technology & Innovation (NACOSTI, License No: NACOSTI/P/24/40,935, approval date 20.05.2024). This study is part of a task within the Horizon Europe-funded WISER project, focusing on links between water (in)security, well-being, and productivity in Nairobi (Foellmer et al., 2025) (Box 1).

2.2.1. Focus group discussions

Our focus group discussions (FGDs) aimed to gather deeper insights related to drinking water supply and quality (Davis et al., 2018); perceived drivers of water insecurity and service interruptions; and coping mechanisms across informal and formal settlements. Participants were asked about different water sources available in their community and, for each mentioned water source, probed on frequency and reliability of supply, perceived quality and seasonal variation, as well as experienced water supply and quality challenges and associated coping strategies. This approach allowed us to capture distinct experiences and perceptions linked to different water sources. Although participants were individual community members, the discussions allowed participants reflect on personal, household, and community-level experiences.

To account for gender and age differences, we carried out separate group discussions with male and female residents, and older and younger residents across settlements. This approach built on previous positive research experiences, where individuals participating in group discussions in Kenya and Zimbabwe felt more comfortable, and more

Box 1

A Horizon Europe study on the effect of water (in)security on perceived well-being and productivity growth. The case of African cities.

This research is part of the Horizon Europe funded project Well-being in a Sustainable Economy Revisited (WISER, <https://www.wiserhorizons.eu/>, grant agreement No 101,094,546), Work Package 4 “The role of social, environmental and governance factors: leaving no person or place behind”. Specifically, it explores interlinkages between water (in)security, human well-being, and productivity growth in urban Nairobi, Kenya. We identify enablers and barriers to well-being and productivity, with a major focus on (a) provision of safe water to prevent water, sanitation- and hygiene (WASH)-related diseases and (b) protection from water-related threats (e.g. flooding) (Foellmer et al., 2025).

A mixed-method, comparative cross-sectional study design is employed in informal and formal settlements. A map-based household survey focuses on interactions between water insecurity (including WASH and flooding), well-being, and productivity. Choice experiments serve to understand residents' preferences for water supply interventions, particularly whether their willingness to pay is driven by productivity or health considerations. Focus group discussions capture collective knowledge, perspectives, and attitudes related to water insecurity and WASH, flood impacts, and links to well-being, and productivity.

Our paper on water insecurity and lived experiences offers an analysis of water insecurity in Nairobi's informal and formal settlements, focusing on HRTW experiences of availability, accessibility, quality, and safety; perceived causes and challenges; seasonal variability; residents' lived experiences of accessing water, and their strategies of coping with water insecurity. Separate analyses examine in greater depth the interlinkages between household water insecurity experiences, health, well-being, and productivity.

Further publications will highlight choice experiment results, address sanitation facilities, challenges, and sanitation-related quality of life as well as flooding, mitigation measures, and compounded risks associated with flood-related water insecurity, building on our work presented here.

open to discuss, in groups with similarly aged peers (Ogutu et al., 2025).

2.2.2. Household survey

A household survey was conducted to collect quantitative data on drinking water supply, including the type of main water source, distance to households, time required per collection trip (UNICEF and WHO, 2018), collection responsibilities (Graham et al., 2016), water treatment practices (Misati, 2016; Mohamed et al., 2025), and basic demographic information.

This study primarily draws on FGDs, through which we aimed to better understand the complexities of residents' water challenges, perceptions, and lived experiences, including links and associations between issues that are often missed by standardised questions and limiting answer options (Wong, 2008). The household survey complements these in-depth insights by indicating how widespread the challenges and perceptions raised in FGDs are within and across settlement types.

2.3. Data collection

Data collection involved three research assistants who (1) had experience in collecting data in the two study sites; (2) an understanding of the study communities; and (3) fluency in the local language (Swahili). Prior to data collection, the research assistants engaged in a 4-day training on the study's objectives, design, research methods and tools (including the FGD guide and survey), ethical considerations, and fieldwork procedures. After training, the survey questionnaire was pretested with community members and revised incorporating feedback from the project and field teams. Qualitative and quantitative tools were translated from English into Swahili by a professional translator and validated by the research assistants to ensure accuracy and cultural appropriateness. Original and translated versions were used, depending on participant preference.

Data was collected from January to May 2025. Each settlement began with FGDs, followed by the survey, starting in Korogocho. A one-day refresher on the FGD guide and survey tool preceded fieldwork in Jericho and Harambee.

2.3.1. Focus group discussions

FGDs were held with support from Community Health Promoters (CHPs) at the village level, whose local networks enabled community entry and recruitment across predetermined disaggregation groups (men and women; 18–49 and 50+).

Eight FGDs were conducted in Swahili, four per settlement (men 18–49, women 18–49, men 50+, women 50+). They took place at a central location (partner site office), with one session at a time to ensure participant comfort. Groups averaged eight participants, lasted 60–90 min, and followed a common protocol. Trained moderators used guiding questions (available upon request) to facilitate discussion and encourage participants to share and respond to each other's experiences (Wong, 2008). Each FGD was audio-recorded, with simultaneous notetaking.

2.3.2. Household survey

Survey respondents and FGD participants were recruited separately, with no individuals participating in both. The survey employed a combination of random and systematic sampling. In Korogocho ward, three of eight villages (Mwau et al., 2012) were randomly selected (Grogan A, Korogocho B, Kisumu Ndogo). In Harambee ward, two neighbourhoods were included (Jericho Lumumba and Harambee estates). Conversations with local representatives revealed informal developments emerging in parts of Jericho Lumumba. Therefore, to preserve the formal–informal comparison, three internally identified sub-areas of Jericho Lumumba and a corresponding area in Harambee estates were purposively selected during site visits to represent locations matching our formal settlement definition (Chrispus and Shema, 2025).

Within selected villages, households were selected from updated lists

provided by CHPs, using a systematic sampling approach commonly applied in African household water studies (Thomas et al., 2020). Based on prior research in low-income urban areas, where approximately 57% of households connected to public or community water systems were found to be water insecure using the 12-item Household Water Insecurity Experiences (HWISE) Scale (Jepson et al., 2021), we estimated a required sample size of 538 households to achieve 80% power ($\alpha = 0.05$) for detecting a 10% difference between sites (Wang and Chow, 2007). Allowing for a 20% non-response rate, this was increased to 646 households to determine selection intervals. Two-thirds of the sample were allocated to Korogocho (2977 households; every 6th household selected) and one-third to Harambee ward (every 3rd household). Higher-than-expected non-response yielded a final sample of 545 households. Data were collected on tablets using SurveyCTO, uploaded daily to a central server, and checked daily for quality and completeness.

2.4. Data analysis

To measure disparities in access to basic water services from a human rights perspective in Nairobi's informal and formal settlements, the analysis applied the normative content of the HRTW as an analytical framework. Quantitative and qualitative findings were organised around availability, accessibility, quality and safety, affordability, and acceptability of water (RQ 1); everyday lived experiences of collecting water (RQ 2); coping strategies (RQ 3); perceived causes of water insecurity (RQ 4); and community recommendations.

FGD recordings were transcribed verbatim via Microsoft Word, translated into English, and reviewed for consistency and accuracy. Multiple researchers developed an initial coding framework structured around the normative dimensions of the HRTW, which served as the primary analytical framework (Fig. 2) and was later expanded with emergent themes. This framework was reviewed and agreed upon by the research team. Emerging codes were merged into themes aligned with the research objectives, and reviewed by a subset of researchers to ensure consistency, adequacy, and completeness. Results are presented with supporting quotations and complemented by quantitative findings, contrasting settlement types, genders, and ages. Participants are identified by settlement type (I = informal, F = formal), age (Y = younger, O = older), gender (M = male, F = female), and participant number. Insights from the water insecurity literature were used to contextualise and interpret the empirical findings. Survey data were analysed descriptively to profile and compare water supply within and across settlements. Percentages and means were calculated, and visualisations generated with Python 3.12.9, using Matplotlib (Hunter, 2007) and Seaborn (Waskom, 2021).

3. Results

A total of 65 participants took part in FGDs (informal: 33, formal: 32, Table 1A). 545 households participated in the survey (informal: 368; formal: 177), predominantly long-term residents and renters, with comparable household sizes and compositions. Women were more often respondents (77.7% informal; 64.4% formal). Respondents were household heads more frequently in informal (56.8%) than in formal (41.2%) settlements. Household heads in formal settlements were predominantly male (78.5%), whereas 40.8% in informal settlements were female. 51.6% of informal settlement respondents had only basic primary schooling, whereas 67.2% in formal settlements had attended college or university. Income in informal settlements was derived mainly from informal work (48.1%), self-employment (25.8%), or mixed sources (21.2%), whereas in formal settlements 36.7% were formally employed, 24.9% self-employed, and 26.6% relying on mixed sources. Financial hardship was higher in informal settlements, with 46.7% reporting “just about getting by”, and 50.3% finding it difficult or very difficult. In formal settlements, 13.6% faced such difficulties, while 44.0% reported “doing alright” or “living comfortably” (Table 1B).

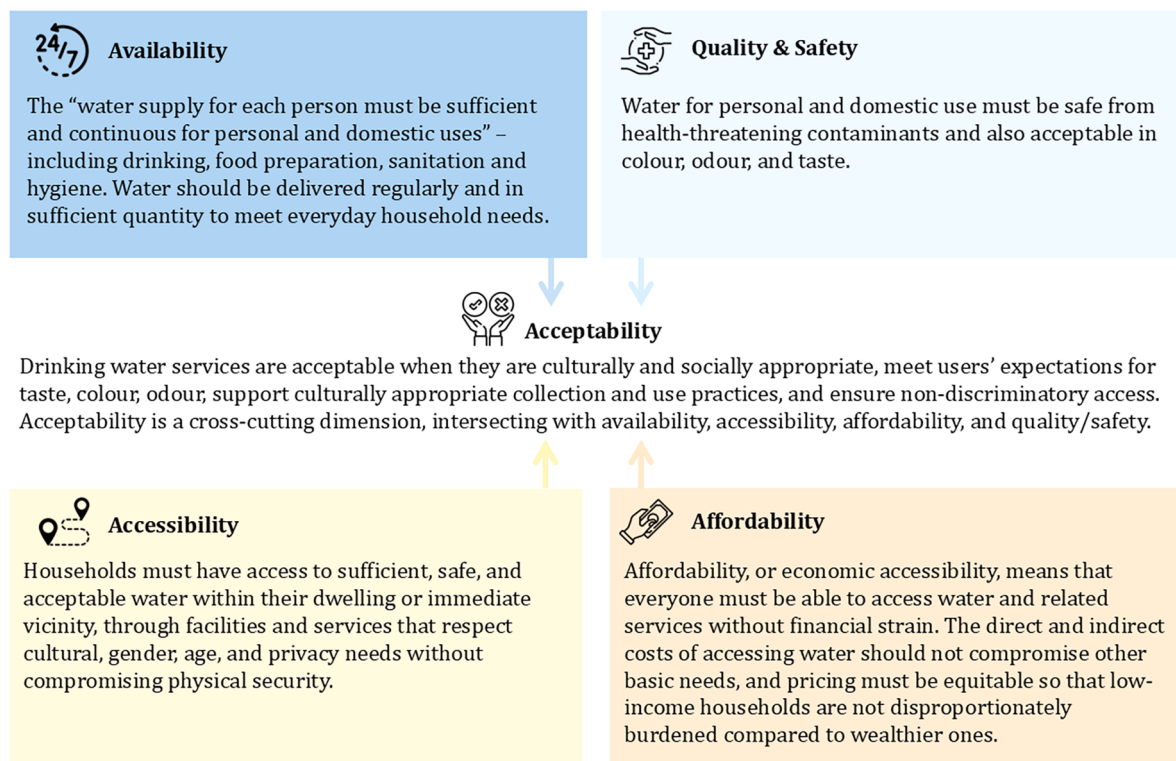


Fig. 2. Normative content of the Human Right to Water (UN Economic and Social Council, 2003).

3.1. The HRTW in Nairobi's informal and formal settlements

3.1.1. Availability, quantity, and reliability

Piped water is the main drinking water source for most households as reported through our survey. In informal settlements, 48.9% reported accessing it in the dwelling, yard, or plot, while others indicated using kiosks (27.2%), public taps (17.7%), or piped water from a neighbour (6.3%). In formal settlements, piped water to the dwelling, yard, or plot was also most common (42.4%), though some households primarily used rainwater (29.9%), bottled (7.3%), or delivered water from carts with small tanks (2.8%) (Table 2). Basic services were available to most households, but according to insights gathered during FGDs, quantity and reliability of piped water remained limited, particularly in informal settlements (Tables 3, 4). Persistent supply interruptions and resulting water shortages affected both settlement types, with water typically available only from Friday to Sunday or Monday morning, and occasional weekday supply in formal settlements. Residents across settlements, genders, and ages described this as “problematic” (I-OF-2); “troublesome” (F-YM-6); and stated that “we are not supposed to live in Nairobi in such a situation” (F-OM-1).

Across settlements, ages and genders, residents highlighted not only frequent water supply interruptions but also their unpredictable timing as challenging. Water was sometimes supplied only part of the day or remained unavailable even when expected, leaving some feeling they “only get the water by luck” (I-OM-1).

3.1.2. Physical accessibility

About half of households (informal: 47.8%, formal: 42.3%) reported accessing their main water source within their dwelling. In informal settlements, the rest collected water within 50 m (47.0%) or 100 m (4.9%). Notably, according to our survey, in formal settlements, 6.9% reported walking 100–300 m or farther, compared with 0% in informal settlements (Table 2).

Most households collected water within 30 min (informal: 72.1%; formal: 83.6%), though longer collection times were more common in

informal settlements (27% vs. 16.4%). Adult women disproportionately bore the burden of water collection, particularly in informal settlements (78.5%). In formal settlements, adult men (20.9%) and non-relatives (21.5%) contributed more, though women were still the main responsible (51.4%) (Table 2).

FGDs revealed that access to piped water was perceived as uneven within settlements. In informal settlements, a young woman explained that supply sometimes did not reach all water points and that some points no longer had water. In formal settlements, all groups highlighted that not all households received piped water. Access depended on household location, proximity to main supply lines, and housing structure, with upper-floor residents often left out due to low water pressure. Some residents had not received piped water for years. Despite intermittent, unreliable and uneven service, formal settlement residents still considered themselves better off than those without any water access (Tables 3, 4).

3.1.3. Quality and safety

Residents' perceptions of piped water quality varied across settlements. Emerging topics in FGDs related to cleanliness and safety as well as service interruptions and seasonal dynamics affecting quality (Tables 3, 4).

In informal settlements, some older residents described piped water as “good because it is treated” (I-OM-4) or “not bad and cannot harm people” (I-OM-3), whereas younger residents noted “salty” and “reddish” water as signs of contamination (I-YF-2, I-YF-3). In formal settlements, water quality was widely seen as poor or uncertain as residents “do not know whether the water is treated” (F-OF-3), sometimes finding it “very dirty” (F-OF-6), “somewhat bitter” (F-OF-2), or having a “severe sewer smell” (F-OM-8). Some individuals considered it “okay” (F-YM-2) and “tasty” (F-OM-8), noting it “quenches thirst unlike borehole water” (F-OM-4). Yet, despite the perceived unsafety, according to our survey results, most households across settlement types did not treat their drinking water prior to consumption (informal: 64.7%; formal: 53.7%) (Table 5).

FGDs revealed that across settlements, genders, and ages, there was

Table 1

Socio-economic characteristics of focus group participants (A) and household survey respondents (B).

A: Focus group participants				
Group	Gender	Age	Informal n	Formal n
YM	Men	18–49	9	8
OM	Men	50+	8	9
YF	Women	18–49	8	8
OF	Women	50+	8	7
B: Household survey participants				
		Informal		Formal
		Percentage	Mean (min, max)	Percentage Mean (min, max)
Living situation				
Years of residence			12 (0, 60)	15 (0, 75)
Occupancy status				
Owner paid off		9.5		5.1
Renter		84.5		94.4
Free of charge by employer/ relative		5.7		0.0
Rent-free		0.3		0.0
Respondent characteristics				
Gender				
Male		20.7		33.3
Female		77.7		64.4
Unknown ¹		1.6		2.3
Is household head		56.8		41.2
Household head characteristics				
Gender				
Male		59.2		78.5
Female		40.8		21.5
Prefer not to say		0.0		0.0
Age (years)			45 (19, 80)	46 (21, 85)
Education				
Not attended school		5.7		0.6
Basic primary education		51.6		1.7
Secondary education		35.9		29.9
Vocational training		0.5		0.6
College/ Uni		6.3		67.2
Years in education			5 (1, 8)	4 (1, 8)
Household composition				
Household size			4 (1, 13)	5 (1, 11)
Number of children			2 (0, 11)	2 (0, 7)
Has members under 18 years		80.7		75.7
Has members over 60 years		16.6		15.8
Has disabled members		6.8		5.1
Sources of income				
Formally employed		2.7		36.7
Informally employed		48.1		10.7
Self-employed		25.8		24.9
Mixed sources		21.2		26.6
Support-based income		1.4		0.0
None		0.8		1.1
Perceived financial situation				
Living comfortably		0.8		14.1
Doing alright		2.2		29.9
Just about getting by		46.7		41.8
Finding it quite difficult		29.6		11.3
Finding it very difficult		20.7		2.3

¹ Respondent gender was derived from household head status, reported sex of the household head, and relationship to household head. “Unknown” indicates cases where gender could not be inferred.

consensus that water quality fluctuates, typically deteriorating after water supply interruptions (Tables 3, 4). Only older men did not prominently highlight this issue. Particularly in formal settlements, residents considered water with visible signs of contamination, such as sand or particles, unusable for drinking and limited its use to domestic tasks like flushing toilets or cleaning surfaces. While the water might

Table 2

Main water sources, their distance to households, the time required for each water collection trip, water collection responsibilities, and support received during water shortage in informal and formal settlements, based on household survey data collected in March–May 2025 in Korogochi (n = 368) and Jericho Lumumba and Harambee (n = 177), reported in % of respondents per response option.

	Informal (n = 368)	Formal (n = 177)
Main water source		
Piped into dwelling, yard or plot	48.9	42.4
Piped to neighbour	6.3	0
Public tap	17.7	6.8
Collected rainwater	0.0	29.9
Water kiosk	27.2	10.2
Delivered water from cart with small tank	0.0	2.8
Bottled water	0.0	7.3
Ferried from upcountry piped water system	0.0	0.6
Borehole, protected well or spring	0.0	0.0
Unprotected well or spring	0.0	0.0
Delivered water from tanker truck	0.0	0.0
Surface water	0.0	0.0
Distance to main water source		
In dwelling	47.8	42.3
< 50m	47.0	16.0
50 m - <100m	4.9	16.0
100m- 300m	0.3	18.9
> 300m	0.0	6.9
Water collection time		
≤15 min	54.2	63.8
16–30 min	18.9	19.8
31–60 min	16.4	6.2
>60 min	10.6	10.2
Water collection responsibility		
Adult male	8.2	20.9
Adult female	78.5	51.4
Child male	5.2	5.1
Child female	6.8	1.1
Non relative	1.4	21.5

appear cleaner over time, “even if you boil, when it settles you see dirt at the bottom” (F-YF-8), indicating ongoing contamination. In blocks experiencing prolonged interruptions, some residents reported finding worms in the water.

Water quality deterioration during the rainy season was widely discussed and commonly agreed upon. Residents noted visual and olfactory changes in the water. Also in informal settlements, younger men and older women raised concerns about water contamination during the rainy season, particularly where leaking pipes run through drainage areas and allow sewage to enter. This rendered the water unsafe for consumption and increased the risk of illness (Tables 3, 4).

3.1.4. Affordability

Affordability of water was a major concern across settlements, genders, and ages, and was widely discussed during FGDs, particularly given the already challenging perceived financial situation, especially in informal settlements (Table 1). Limited and unreliable water supply drove up prices, forcing households, particularly those with children, to spend a substantial share of income on water, often at the expense of other essential needs, with accumulated pending water bills further increasing financial pressure.

In informal settlements, FGD participants reported diverting funds from food (skipping meals or eating outside due to lack of cooking water), hygiene products (soap), and school needs (cleaning uniforms) (Tables 3, 4). Survey data confirmed that households most often cope with financial hardship by skipping meals (28.0%) or spending less on food and essentials (16.6%), borrowing from social networks (52.4%), and using credit (17.4%). Financial constraints were also a main reason for not treating water, particularly in informal settlements, even if perceived unsafe (informal: 23.0%; formal: 5.3%) (Table 5).

Table 3

Summary of focus group discussion findings (January–April 2025) from informal (Korogocho) and formal (Jericho Lumumba and Harambee) settlements, with 65 respondents across 8 FGDs (young and older women and men per settlement), analysed in relation to the normative content of the Human Right to Water (availability, accessibility, quality and safety, affordability, and acceptability). X = topic mentioned at least once, (X) topic mentioned indirectly.

Theme	Informal				Formal			
	YM	OM	YF	OF	YM	OM	YF	OF
	n = 9	n = 8	n = 8	n = 8	n = 8	n = 9	n = 8	n = 7
Availability of piped drinking water								
Frequent supply interruptions	x	x	x	x	x	x	x	x
Unreliable timing of availability	x	x	x	x	x	x	x	x
Physical accessibility of piped drinking water								
Uneven access within settlements			x	x	x	x	x	x
Quality and safety of piped drinking water								
Perceived as safe/tasty		x	x	x	x	x		x
Perceived as uncertain	x		x				x	x
Perceived as unsafe		x	x	x	x	x	x	x
Worsens after interruptions	x		x	x	x		x	x
Worsens in rainy season	x		x	x	x	x	x	x
Quality and safety of alternative water sources								
Borehole water salty and unsafe	x	x	x			x		
Borehole water salty but safe					x	x	x	
Vendor water quality is uncertain	x				x		x	x
Rainwater for non-consumptive use				x			x	x
Affordability								
Consuming large share of income			x	x	x	x		
Trade-offs with other basic needs		x		x	x			
Higher costs during shortages		x	x	x			x	x
Cost of water collection	x	x	x	x				
Higher costs of alternative sources					x		x	x
Cost of treatment					x	x	x	
Acceptability and lived experiences								
Time burden of collection			x	x				
Inconvenient timing of availability			x		x			x
Health & well-being impacts		x	x	x		x		x
Conflicts	x	x	x	x	x		(x)	(x)
Accountability: Water shortage and service interruptions								
Population growth				x		x		x
Broken & ageing infrastructure	x	x	x	x	x	x	x	
Governance challenges & inaction		x		x		x		
Illegal connections to water supply	x			x		x		
Low water pressure & water pumps					x	x	x	x
Absence of monitoring & enforcement	x							
Vending cartels	x							
Accountability: Poor piped water quality								
Water provider seen as responsible	x				x			

Table 3 (continued)

Theme	Informal				Formal			
	YM	OM	YF	OF	YM	OM	YF	OF
	n = 9	n = 8	n = 8	n = 8	n = 8	n = 9	n = 8	n = 7
Community practices	x							
Broken pipes	x	x	x	x	x	x	x	x

In formal settlements, FGD participants limited bathing, laundry, and overall water use to manage expenses, highlighting the wide-ranging impact of unaffordable water on daily life and well-being, even “the security of their life” (F-OM-9), raising the dilemma “will you pay for water or survive?” (F-YM-7) (Tables 3, 4). Survey findings indicated that formal-settlement households primarily reduced non-essential spending (61.0%), borrowed from social networks (31.6%), and used savings (25.4%) during financial hardship, though cutting expenses for food and essentials (19.8%) and skipping meals (11.3%) remained common (Table 5).

Water supply interruptions sharply increased prices across settlements, as highlighted during FGDs. Households unable to fetch water during limited availability or whose stored water ran out had to purchase additional jerrycans, often at higher prices. In informal settlements, the cost of a 20-litre jerrican at the water kiosk or from water vendors could rise from Kenya shilling (KES) 5 to KES 50–100 during shortages (I-OM-4, I-OM-6), sometimes with additional delivery fees (I-OM-4). In formal settlements, even among households with greater storage capacity, interruptions also forced unplanned purchases, with jerrican prices reaching KES 30–40 (F-YF-8). Across settlements, these increases intensified financial strain, particularly for households with limited storage and financial resources. Prices also varied within settlements depending on location or relationships with vendors, adding to financial unpredictability, as described by an older formal-settlement resident (Tables 3, 4).

Collecting water incurred further costs in informal settlements. Households may need to hire hand carts for transport for KES 200 (I-OM-2) or pay others to fetch water when unavailable or unwell (I-YM-4, I-YF-2, I-OF-3), diverting money from other essentials like food. At times, trips were wasted when water was unavailable, forcing additional trips and costs (Tables 3, 4). Poor water quality further undermined affordability across settlements, forcing expenses for safer sources, treatment (Table 5), or healthcare to treat waterborne diseases.

Together, these dynamics translate into unreliable water access in terms of quantity. This creates a reinforcing cycle in which insufficient water forces residents to ration use and postpone tasks, limiting their ability to plan essential chores like cooking, cleaning, and bathing, and compromising hygiene and nutritional intake. The resulting health risks can reduce school attendance and income-generating activities, further constraining financial resources and deepening water insecurity and affordability pressures (Foellmer et al., 2025), as explored in greater depth in a forthcoming paper (Box 1).

3.2. Everyday lived experiences of accessing water

Frequent interruptions and unpredictable water supply, uneven access, and poor quality shaped residents’ everyday water insecurity experiences, imposing financial and time burdens, shaping household responsibilities, and generating frustrations and conflicts around water collection.

3.2.1. Time burden of accessing water

Time burden was raised mainly by younger and older women in informal settlements during FGDs (Table 3). Women highlighted the burden of long queues with waiting times of three to four hours due to limited and supply (Table 4). Survey data confirmed that adult women

Table 4

Selected quotes illustrating Human Right to Water dimensions in formal and informal settlements in Nairobi, Kenya. Based on 8 focus group discussions (January–April 2025) with 65 participants (younger and older women and men) from Korogocho (informal) and Jericho Lumumba and Harambee (formal) settlements.

	Informal	Formal
Availability	“Water is problematic in Korogocho. People do not get enough water” (I-OF-2) “We only get the water by luck” (I-OM-1).	“Water does not stay from morning to evening, and may be unavailable during the day.” (F-OF-2) “Some days you may expect water and find no water.” (F-YM-6)
Accessibility	“Sometimes water supply does not reach all the points but just at one point. You also find that the points where we used to access water no longer have the supply of the commodity.” (I-YF-6)	“There are people who have not received [piped] water in the past 5–10 years” (F-YM-8) “You cannot compare us with places where people don’t access water completely. [...] We are a bit better because at least we receive some amount even though it’s not sufficient.” (F-OM-7)
Quality and safety	“If a pipe has stayed for three days without water, when the water comes, it first washes the pipe. I mean, for two to three hours, the water is in a bad state of quality.” (I-YM-2) “During the wet season [the quality of water is not good because] water from the overflowing drainages penetrate into the pipes.” (I-YM-8)	“Immediately after rationing, water flows with sand particles. This water cannot be used for drinking and cooking. It can only be used in the toilet or cleaning surfaces.” (F-OF-5) “Most of the time, it will look clean but in a white jerrycan, you will either see that it’s brown or when it settles, you will see residue at the bottom. During the rainy season, it’s usually dirty.” (F-YF-3)
Affordability	“As soon as water supply is back after a long period of unavailability, the vendor increases the price drastically. When it becomes available in other places, the price drops. It causes poverty.” (I-YF-1) “In KB we get water once per week. If you do not fetch water that Friday or Thursday, you will be forced to dig deeper into your pocket. [...] If you do not have money and water, you will suffer. The normal price of a 20-litre jerrycan can go for up to KES 50. The normal price at a vendor is KES 5. Sometimes it can even go for KES 100 when the taps run dry.” (I-OM-6)	“Whichever small that you earn, you end up spending it on water.” (F-OM-6) “A big challenge arises when the Nairobi City Council water is not available because buying becomes very expensive. You have to limit water [use] because one jerrycan costs KES30 or KES 40.” (F-YF-8) “Shortage of water forces you to buy water and incur a cost you didn’t anticipate.” (F-OF-7) “For a vendor that knows me, I buy it at KES 20. [...] If you live upstairs, the price increases. You can even pay up to KES 70.” (F-OM-8)
Acceptability: time burden	“Sometimes you may find a long queue, with 100 jerrycans ahead. So, you will have to wait for 3 to 4 h before you access the water.” (I-YF-2) “I will wake up at night to queue for fetching water. If I know that the following day I will be going to my laundry work, I will ensure I am the first one on the queue. I will fetch to my satisfaction before other	“If you don’t have a pump, you will have to wake up at 2 am so that you can fetch. The supply is not consistent and the pressure cannot reach everyone’s house” (F-YM-7); “If you do not have a tank or drum, you may fetch using lots of jerrycans [...] until late night (12–1 am)” (F-OF-5).

Table 4 (continued)

	Informal	Formal
Conflicts	people wake up. The issue is always the queue.” (I-OF-5) “When there is water, you may find one person bringing his 30 jerrycans, another person 10, by the time they are done fetching, the taps run dry.” (I-OF-5) “If in a queue I put my jerrycans ahead of another person, the person can start using abusive language on me. This is how conflicts begin due to water issues.” (I-OM-4) “Sometimes you can go for water and find a queue of many people and others fighting for the water, thus you can even get injured. So, you go back to the house and by the time you come back, the water is unavailable.” (I-YF-3) “When we go to fetch water, noises from the queue disturb the people from that area and they cannot sleep, they cannot sleep due to noise from the jerrycans and people.” (I-OF-4) “Your jerrycan may be stolen or the water inside removed by another person. Someone may come and find your jerrycans filled with water and empty the water into their jerrycans while you are away taking some jerrycans to your house. Keep in mind you have already paid for the jerrycans.” (I-OM-5)	“It creates enmity. Your neighbour may stop talking to you; when he sees you it feels like he has seen an enemy.” (F-YM-6) “Since we have differences in income, I will be bitter with my neighbour who has a pump. He can’t pump water the whole day since water is available for only two days; he has to give me time to fetch too. I may be forced to stay awake the whole night so that I can fetch and miss going to work the following day while he is going on with his activities. It brings conflicts and disagreements.” (F-YM-7) “Water insecurity also brings family conflicts.” (F-OM-6)
Acceptability: Health and well-being impacts of water collection	“If there is a water shortage your daughter goes a long distance to search for water, she may be gone for two hours. She may come back pregnant. If water is close, she won’t go away.” (I-OF-4) “You woke up at 3am and finished fetching at 4am. You cannot go back to sleep at that time because you will only bathe and go to work. Your body will be fatigued and you will be sleepy.” (I-OF-2) “Children suffer when I wake them up at 3am to queue for water. That child won’t be happy the whole day because didn’t get enough sleep. The child’s life is affected.” (I-OF-3) “You are not at peace queueing for water as you do not know what happens to your house.” (I-OF-4)	“Sometimes we fetch water when it is raining or when it’s very cold. If you are not properly warmly dressed in a jacket and the water splashes onto your cloth, you may suffer from pneumonia.” (F-OM-1) “Lifting a jerrycan from the ground to upstairs needs energy. You need to eat a lot of food.” (F-OM-9) “Carrying water upstairs has caused the backs of a lot of women to break. Our backs are not operating well due to carrying water upstairs.” (F-OF-4)

Table 5

Household coping strategies in informal (n = 368) and formal (n = 177) settlements, based on household survey data collected in March–May 2025. Coping strategies include water treatment methods and reasons for not treating water, support received during water shortages and financial hardship. Water treatment methods are reported as the percentage of households using each method. Reasons for not treating water were obtained through an open-ended question and are reported as the percentage of all reasons mentioned; households could report multiple reasons. Support received reflects the percentage of households reporting assistance during water shortages or financial hardship, multiple responses possible.

	Informal	Formal
Water treatment methods	(n = 368)	(n = 177)
None	64.7	53.7
Boil	23.6	27.1
Add bleach	9.5	16.9
Stand and settle	0.3	0.0
Water filter	0.0	2.3
Other	1.9	
Reasons for not treating water	(n = 270)	(n = 95)
Perceived safety	40.4	84.2
Financial constraints	23.0	5.3
Lack of supplies	10.0	0.0
Habit	7.4	5.3
No treatment plan	6.7	0.0
Energy/Fuel constraints	5.9	0.0
Time constraints	2.2	1.1
Change in taste	1.9	1.1
Faith	0.7	0.0
Low awareness	0.4	0.0
Convenience	0.4	0.0
No reason	0.4	2.1
Other	0.7	1.1
Support received during water shortage	(n = 368)	(n = 177)
Water	67.1	58.2
Childcare	9.8	0.0
Money	3.8	0.0
Groceries	0.8	0.0
Other	2.2	0.0
None	29.9	41.8
Coping strategies during financial hardship	(n = 368)	(n = 177)
Using less water	0.3	6.2
Skipping meals	28.0	11.3
Spending less on food/essentials	16.6	19.8
Using less fuel (gas/electricity)	0.3	2.8
Spending less on non-essentials	14.1	61.0
Using savings	7.3	25.4
Using more credit	17.4	3.4
Borrowing from social network	52.4	31.6
Borrowing from bank	0.5	11.3
Borrowing from private lender	5.2	8.5
Working extra hours	8.2	5.6
Other	35.6	15.3
Getting food on credit	9.8	1.7
Borrowing from shops	3.3	1.6
Getting commodities on credit	3.0	6.8
Nothing/ Not applicable	2.7	2.3

disproportionately bore the burden of water collection (informal: adult female 78.5% vs. adult male 8.2%; formal: adult female 51.4% vs. adult male 20.9%) and collection took longer in informal settlements (Table 2).

Beyond duration, timing was considered highly inconvenient. In informal settlements, young men and women described queuing at night to secure water before supply stopped: “*When it’s opened [water supply], you have to go for it at 1 am and scramble to access it*” (I-YF-3). In formal settlements, households without pumps or water tanks adjusted routines to brief times of higher pressure, often disrupting sleep disruption by staying up late or getting up early (Tables 3, 4).

3.2.2. Conflicts over accessing water

Conflicts over accessing water were reported in both settlements during FGDs (Tables 3, 4). In informal settlements, women and men

across ages described frequent conflicts at public taps. Disputes arose over queuing and fairness, as some residents filled numerous jerrycans, repeatedly refilled their containers, added jerrycans mid-queue, or tried to overtake others – acting as if they “*own[ed] the water tap*” (I-OM-5). Such incidents lead to arguments, verbal abuse, and occasionally physical fights, particularly discussed among women but also older men. A young woman reported that avoiding conflict at crowded taps risked missing out on water if it ran out before they returned. Noise from crowded nighttime queues and jerrycans disturbed nearby households, causing loss of sleep.

Theft was another concern. An older man explained that unattended jerrycans, e.g. when collectors briefly stepped away to bring jerrycans into the house, could be stolen or emptied by others after payment. These experiences underscored how scarcity undermined trust, social relations, and personal security.

In formal settlements, tensions between households with and without pumps came up in all groups. Pumps enabled some to draw large volumes quickly, reducing pressure for others who still paid water bills but received little or none. This unequal access fostered frustration and strained neighbourly relations, stressed particularly by younger men and an older man. Some described feeling “*enmity*” (F-YM-6) and “*bitter*” (F-YM-7) toward neighbours with pumps, experiencing conflicts over concurrent use during peak supply times, lost sleep from nighttime collection and missing work the following day, highlighting how income differences intensified water-related stress. Women did not explicitly describe conflicts, but highlighted competition during supply windows between households with and without pumps, and challenges faced by upper-floor residents due to low water pressure.

Water insecurity also disrupted intra-household relationships. Older men described conflicts over collection responsibilities, especially when weekend supply clashed with social plans or rest, creating tension between spouses and other household members. Youth attending social activities may leave older members to fetch water. One older man explained that if he went out while his wife fetched water, returning late and going straight to bed could create tension. Frustration grew when one member stayed awake to fetch water only for others to use it the next day, making collectors angry and causing “*fights in households*”. If the collector became “*annoyed*” and skipped fetching water, they could be forced to buy expensive water the following week, further exacerbating conflict (F-OM-3). Water insecurity intensified household conflicts when the same person was repeatedly expected to fetch water, supply interruptions or small quantities made collection difficult, and when failure to fetch or purchase water led to disputes (F-OM-6). These examples highlight the intra-household strain created by limited and unpredictable access.

3.2.3. Health and well-being implications of water collection

Older women and men across settlements, and younger women in informal settlements, reported multiple physical, emotional, and safety-related impacts of water collection during FGDs (Tables 3, 4).

Physical health risks arose from collecting water at night or in adverse weather with inadequate clothing, exposing individuals to cold, increasing the risk of illnesses such as pneumonia and associated health costs across settlements. In formal settlements, lifting and carrying jerrycans, particularly upstairs, caused fatigue, back injuries, and higher nutritional demands. Safety concerns were particularly pronounced in informal settlements, where caregivers feared that children, especially girls, faced abuse or sexual assault when travelling long distances and spending extended time collecting water.

Sleep disruption and fatigue were widespread. Nighttime water collection prevented adequate rest, causing physical and mental fatigue and reducing functioning at work or school. Particularly children woken early to fetch water experienced adverse impacts on well-being and mood, leading parents to describe the experience as “*you torture your children*” (I-OF-5).

Emotionally, water collection induced stress and worry, including

feeling rushed to avoid losing water, anxiety about leaving homes unattended, and fear of theft.

These findings highlight the multifaceted burdens of water collection on health, safety, and well-being, affecting adults and children across settlement types.

3.3. Coping strategies and their affordability

Residents across settlements coped with unreliable supply by using alternative sources, switching between them, storing water, and adjusting daily routines as revealed during FGDs in particular. These coping strategies highlight reliance on decentralised alternatives, with added financial burdens and health concerns due to uncertain quality, while community efforts provided additional support in managing water insecurity.

3.3.1. Storage of piped water when available

Households stored water during supply days to bridge interruptions. In informal settlements, limited storage infrastructure, such as donated tanks, were seen as a major constraint, while water from private tanks was often unaffordable. Storing water in jerrycans was feasible only for households able to afford both containers and extra water. Having many jerrycans allowed households to purchase additional water when available and more affordable than during service interruptions, though transport, such as hiring carts, added extra costs depending on the distance to the water source (Tables 3, 4).

In formal settlements, wealthier households used tanks and pumps to store water beyond weekends, though meeting weekday needs remained “a challenge during weekdays” (F-OM-5), leaving households to “suffer a lot” (F-OF-1). Families with children faced added pressure to ensure sufficient storage (F-YF-6).

3.3.2. Alternative water sources

In informal settlements, according to FGDs, alternative sources included a school borehole, generally considered inadequate and of poor quality, salty, requiring treatment, and only usable for non-consumptive purposes, e.g. in construction or for washing even though it “is hard water and makes one use a lot of soap during laundry” (I-OM-6). In formal settlements, boreholes were said to have treatment and pumping systems, providing more reliable quality, even though residents still disliked its taste. Only one older man considered borehole water “not clean” (F-OM-9), while younger and older men agreed on its consistent quality throughout the year (Tables 3, 4).

Water from vendors – delivered from other areas in carts, tanks, or trucks, stored in tanks, and sold by jerrycan, often at high prices – was a widely used alternative in both settlements, though its quality was perceived as uncertain. Younger men and older women across settlements, and younger women in formal settlements expressed doubts about water, container cleanliness, and treatment. Yet, households still purchased vendor water due to lack of alternatives. In formal settlements, it was reportedly mainly reserved for non-consumptive uses, such as cleaning and washing, while bottled water was bought for consumption, creating additional expenses on top of regular water bills.

Rainwater harvesting was used across settlements during the rainy season, but generally considered unsafe for drinking due to contamination risks. In informal settlements, residents regarded cats defecating on roofs as a contamination source. In formal settlements, dirty iron sheets or asbestos roofing raised health concerns, including cancer risks. Residents therefore considered rainwater as a supplementary source for non-consumptive, domestic use like laundry or cleaning.

3.3.3. Switching between water sources

Residents described combining vendor, borehole, and rainwater sources, depending on availability, cost, and perceived quality. Women typically prioritised safer sources, such as bottled water, for drinking and cooking, using less safe sources for laundry or cleaning. During the

rainy season, piped or collected water was often used only for laundry, while bottled water was purchased for drinking, increasing financial burden.

3.3.4. Household water treatment practices

Water treatment was applied to mitigate risks from uncertain or poor-quality sources, particularly during the rainy season, according to FGDs.

According to our survey, in informal settlements, 35.3% of households treated water, mainly by boiling (23.6%) or adding bleach (9.5%). In formal settlements, 46.3% reported treating water – also mainly by boiling (27.1%) or adding bleach (16.9%) (Table 5) – when it looked dirty, tasted unusual, or as a precaution during the rainy season. Despite the time and effort involved, treatment was described as part of daily life. In formal settlements, young women highlighted that uneven knowledge among household members sometimes led to incorrect treatment dosages, reducing effectiveness and posing health risks either from chemical exposure or unsafe water.

Non-treatment was common across settlements but for different reasons. In informal settlements, common reasons included perceived safety (40.4%), cost (23.0%), lack of supplies (10.0%) or treatment plans (6.7%), and habit (7.4%). In formal settlements, perceived safety was the main reason (84.2%), with fewer mentions of cost (5.3%), habit (5.3%), taste (1.1%), or time (1.1%) (Table 5). FGDs revealed that treatment costs – from purchasing treatment tablets, boiling water using fuel such as gas, or buying clean water – still imposed an economic burden and further reduced water affordability, making it difficult for households to accumulate savings. One resident noted that years spent on treatment costs prevented investment in property, highlighting the long-term economic impact. Besides, the required time was considered annoying.

Not treating water, in turn, risked diseases, which imposed extra healthcare costs, including hospital visits and medication, further straining household budgets across settlement types. Access to clean water directly from the tap would save time and costs of treatment as well as healthcare costs from unsafe water.

3.3.5. Collective action and community support

In both informal and formal settlements, the majority of households received support during water shortages, primarily through sharing water (67.1% and 58.2%), while in informal settlements some also received childcare (9.8%) or financial help (3.8%). Nevertheless, 29.9% in informal and 41.8% in formal settlements reported receiving no support (Table 5).

In formal settlements, younger and older women highlighted the key role of community spirit during FGDs. They described coordinating with landlords or neighbours to repair broken infrastructure, though cooperation varied. Some said only affected residents acted when pipes burst, while others noted that unity depended on the neighbourhood, with limited face-to-face interaction and reliance on WhatsApp communication reducing collective engagement.

In informal settlements, residents described borrowing from neighbours during shortages. Younger women also borrowed money to buy water from vendors, which caused worry, tension, and loss of peace, and strained relations with vendors when debts went unpaid.

3.4. Accountability: perceived causes of water insecurity

3.4.1. Water shortage and service interruptions

Malfunctioning and ageing infrastructure was seen as a key driver of water insecurity across settlements (Table 3). In informal settlements, men noted “non-functional” boreholes (I-YM-1). For piped water, older residents reported ageing pipes, faulty vending machines, and poorly repaired leaks increasing contamination risks. Similarly, formal settlement residents across genders and ages reported blocked and damaged pipes, with some noting selective repairs.

Rapid population growth outpacing infrastructure expansion was another key concern. In both settlements, older women and men noted that systems built for smaller populations had not expanded, leaving supply unchanged despite rising demand.

Governance failures and government inaction compounded these issues. Informal settlement residents felt neglected by NCWSC. In formal settlements, older men expressed frustration that collective efforts to address water and sewage issues were met with limited government support. One described raising funds to fix a broken sewer line, but facing high material fees and government indifference, leaving residents “demoralised”. After a year, they reached senior management for support, highlighting the importance of community solidarity in pushing for change amid institutional neglect: “If we did not join hands, we would still be in the same situation” (F-OM-9).

Illegal water connections were perceived to exacerbate shortages across settlements. In informal settlements, residents reported that informal connections to NCWSC’s token-operated pipes caused shortages and wastage, worsened by weak monitoring and enforcement. NCWSC did not follow up on installed infrastructure to ensure taps and pipes were used as intended (I-YM-5). In formal settlements, unaffordable tariffs prompted illegal connections, which an older man suggested could have been avoided through public consultation (F-OM-1).

Insufficient water pressure was a key concern in formal settlements, leading some to uninstall meters and fetch water directly. Pumps became essential, yet unaffordable for many households, deepening inequality. This concern was not raised in informal settlements.

Water “vending cartels” were another perceived cause in informal settlements, deliberately disrupting supply to inflate prices. Locally called cartels, these informal vendors illegally access government water, often paying bribes, store it in private tanks, and sell it at high, fluctuating prices, on average four times the cost of municipal sources such as NCWSC (Joshi et al., 2023).

3.4.2. Poor piped water quality

Old or damaged pipes were widely discussed as the main source of contamination across settlements. In informal settlements, all groups but older men expressed concerns about leaks and pipes running through unsanitary areas. A young man also highlighted metal pipes as causes for contamination and diseases like typhoid. In formal settlements, residents across genders and ages similarly linked pipe leakages to contamination from surface runoff and sewage (Table 3).

Poor maintenance and inadequate wastewater treatment from water providers was debated among younger men across settlements. The role of water users themselves was also raised in informal settlements. Informal connections contaminated water, especially near drainage or unsanitary areas, and leaking pipes allowed people to collect potentially unsafe water (Table 3).

3.5. Community recommendations

Improved storage and infrastructure expansion were key priorities in informal settlements. FGD participants called for tanks to help manage shortages between supply days, expansion of the water pipe network, and drilling boreholes in each village. Private taps and meters at the household or plot level were also strongly desired to save time and money, reduce disputes, and ensure fair billing based on individual use.

Infrastructure maintenance and upgrading were recommended, including replacing corroded metal pipes with durable plastic ones to prevent leakages and contamination, particularly during supply interruptions and rainy seasons. Concerns about privatisation and vandalism of donated water facilities such as tanks and distribution lines led to calls for a government-supported, community-based body to oversee and safeguard water infrastructure in order to promote accountability, prevent misuse, and ensure equitable and sustainable access to clean water.

More reliable and frequent water supply – three to four days a week,

without interruptions during supply windows – was seen as essential for meeting basic needs, maintaining hygiene and sanitation, freeing time for income generation, and improving well-being.

Government support for water treatment supplies and for greater community education on water quality and sanitation was requested by some. Younger women linked improved and reliable access to improved well-being and “peaceful coexistence in the community” (I-YF-1).

Improved hygiene and water handling practices among water kiosks and vendors was recommended in informal settlements, where dependence on small-scale suppliers during water interruptions is high. Residents raised concerns about poor hygiene and uncertain water quality, as containers and storage tanks are rarely cleaned, posing serious contamination risks. Regular training and awareness programs on hygiene, water handling, and safe distribution practices were proposed to improve water quality, minimise contamination, and build community trust in informal water systems.

Better infrastructure, governance, and affordability measures to ensure fair and reliable water access were emphasised in formal settlements. Residents called for equitable water pipe expansion and regular maintenance to identify underserved blocks, and better monitoring to prevent water contamination. Access to clean water directly from the tap was viewed as a way to reduce health risks and treatment costs.

Fair pricing and billing reforms were also proposed. Formal settlement residents suggested waiving pending bills and introducing affordable flat-rate payments to replace estimated charges, perceived as unfair. This would encourage consistent payment, improve cost recovery for suppliers, and ensure that all households maintain reliable access to clean water services, promoting both financial inclusivity and long-term sustainability of water provision. Greater representation and direct dialogue between communities, government authorities, and NGOs were seen as essential to ensure local water concerns are heard and addressed effectively.

Gender-inclusive water governance was strongly emphasised by female participants across age groups, especially in informal settlements. Bearing primary responsibility and burden for household water handling and health, they expressed frustration over being excluded from key decision-making processes regarding water provision and management, which limits effective community solutions and positive health outcomes. Including women in leadership and planning would ensure their experiences, challenges, and priorities inform decisions. This would promote equity, community participation, and more responsive and sustainable water management.

4. Discussion

4.1. The HRTW in informal and formal settlements of Nairobi and beyond

Our study indicates that the Human Right to Water remains largely unmet in informal and formal settlements of Nairobi. Looking at the reported water insecurity and lived experiences through a HRTW normative content lens, our FGDs revealed that residents lack available, accessible, affordable, acceptable, and safe water (Table 3).

Availability of piped water is limited by frequent supply interruptions, resulting in intermittent service provision, and water shortages on weekdays in both settlement types. When drinking water is available is largely unpredictable. Although about half of households access water within their dwelling in each settlement type, accessibility is constrained by uneven distribution and service delivery. Water collection times further reduce accessibility, particularly in informal settlements, where many residents spend over 30 min, sometimes over an hour, fetching drinking water.

To cope with water inaccessibility, residents commonly connect illegally to water supply networks, particularly in informal settlements, which compromises quality and safety, as leaking pipes contaminate drinking water. Broken and ageing infrastructure further reduce water quality and safety in both settlement types, creating health risks for

users. Quality and safety also worsens after supply interruptions and during rainy seasons. Across settlements, households treat water when quality seems compromised, though non-treatment is common – driven by perceptions of safety, cost, time, or lack of supplies – highlighting gaps in consistent access to safe and acceptable water.

Acceptability of drinking water supply is reduced by limited availability, accessibility, quality and safety, and by major time burden of collection – borne primarily by women – as well as inconvenient timing of water access, particularly in informal settlements. Low water pressure in formal settlements reduces acceptability further. *Affordability* constitutes another major challenge for residents across settlements, as supply interruptions, water shortages, and low water quality increase financial burdens. Women are particularly challenged in all HRtW dimensions.

Our Nairobi case mirrors challenges across informal settlements in the Global South, where the HRtW remains unrealised through high costs, unreliable supply, and time burdens (Adams et al., 2022; Danti, 2018; Sarkar, 2020; Walnycki, 2015). In Nairobi, poor infrastructure – including intermittent supply and low-quality pipes in unsanitary areas – violates the HRtW and forces residents to rely on unsafe, often seasonally variable sources, as also documented in South Africa and Malawi (Adams, 2018a; Roaf et al., 2020; Social Justice Centres Working Group, 2020; Adams et al., 2022). Similar exclusions are also evident in high-income contexts, where marginalised groups such as Roma in European informal settlements (Anthonj et al., 2025a; Davis and Ryan, 2016) and people experiencing homelessness in Germany (Anthonj et al., 2024) face persistent barriers.

Residents of informal settlements pay substantially more for water than those in formal settlements, often consuming a large share of household income, a situation worsened by water cartels and corruption (Giné-Garriga et al., 2017; Roaf et al., 2020; Social Justice Centres Working Group, 2020). Even within low-income settlements, household socio-economic status shapes water access, including source, quantity, collection time, and affordability (Adams, 2018a). Consistent with our findings, wealthier households cope by storing or purchasing more water, while poorer households face greater time and labour burdens, reflecting inequalities in both access and coping capacity. Physical accessibility challenges disproportionately affect women, who encounter environmental hazards and social risks during water collection, leading to higher physical and emotional health burdens of water insecurity (Adams et al., 2022).

4.2. Availability, accessibility, affordability, acceptability, and quality and safety of water vary with settlement type, gender, and age

While a small number of studies have examined realisation of the HRtW in informal settlements, e.g. in India (Gimelli et al., 2018; Wagle, 2023), Bolivia (Walnycki, 2015; Wutich et al., 2016) and Sweden (Davis and Ryan, 2016), to our knowledge, this is the first study to systematically apply the HRtW normative content to compare lived water insecurity experiences across informal and formal settlements in Nairobi, disaggregated by gender and age.

FGD results indicated that all dimensions of the HRtW are challenged in both settlement types. Water availability, affordability, and quality and safety of water are issues reported in both settlement types. Accessibility and accountability related to water shortage and service interruptions are reported more in formal settlements, whereas acceptability and accountability related to poor water quality are addressed more in informal settlements. These differences reflect variations in distribution and reliance on NCWSC services. Formal settlements generally have household-level metered connections, meaning residents experience service disruptions directly and therefore place greater emphasis on accountability from the water utility. Informal settlements often rely on community water points or kiosks supplied by NCWSC. Households are accustomed to rationing and storing water, and usage patterns are typically lower. Water quality at these points is often poor,

particularly after service interruptions, explaining higher reporting of acceptability and accountability related to water quality.

Gendered differences in water experiences are also evident. While both women and men highlighted availability problems, women more often reported struggles with accessibility, water quality and safety, acceptability, and affordability. Men more often addressed accountability related to water shortage and service interruptions and poor piped water quality. Differentiated water access and experiences between women and men have been documented previously (Harris et al., 2017), and our study confirms this. While other HRtW dimensions have not been analysed by gender yet, this study offers first insights. Considering that women in Sub-Saharan Africa commonly bear water-fetching and domestic health-related responsibilities, and face greater water-related risks, it is unsurprising that they report more challenges with water access, quality, safety, acceptability, and affordability (Cole et al., 2024; Dickin and Caretta, 2022; Van Houweling, 2016). Conversely, men's greater reporting of water accountability issues reflects their more prominent role in decision-making, from which women are often excluded (Adams et al., 2018).

Age-related differences are less pronounced. Water availability, accessibility, affordability, and quality and safety were problems reported regardless of age. Yet, acceptability and accountability concerning water shortage and supply interruptions were mentioned more by older adults, while accountability related to poor water quality was addressed more by younger adults. Although age has previously been found to determine water- and health-related knowledge, attitudes and practices (e.g. Jones et al., 2005; Maniragaba et al., 2023), this represents the first age-group related analysis and comparison related to the HRtW.

4.3. Drinking water service levels in Nairobi informal and formal settlements relative to national contexts

To monitor and track progress towards universal access to safe drinking water under SDG 6 (United Nations, 2015b), the Joint Monitoring Programme (JMP) classifies services by improved vs. unimproved sources and collection time, also considering the safety of management (UNICEF and WHO, 2025). Using this classification, we can contextualise our survey results from informal and formal urban settlements against national, urban, and rural coverage in Kenya.

According to global estimates, at the national level, 65.6% of the population used basic water services, 8.8% limited, 6.7% unimproved, and 18.9% surface water in 2024. In urban areas, 88.9% used basic services and 5.1% surface water (WHO and UNICEF, 2025). In our formal settlements, 83.1% of households used basic services and 16.9% limited services. In our informal settlements, 73.3% used basic services and 26.7% limited services. This suggests that drinking water service levels in urban informal settlements are lower than in urban and formal settlements, but still above the national and rural averages as per the JMP (Fig. 3). For regional context, see the Supplementary File, which compares our Nairobi case and Kenya's national urban water service coverage with other West and East African countries.

4.4. Forms of fluidity in water practices

We sampled individuals and households from informal versus formal settlements based on respondents' place of residence, distinguishing formal settlements that “comply with legal and regulatory frameworks” from those that “arise without official sanction and often lack basic services and infrastructure” (Chrispus and Shema, 2025: 3). This binary framing, however, obscures the incremental and overlapping nature of urban development and limits recognition of partial improvements or hybrid forms that exist between the two (UN-Habitat, 2025). While this distinction was analytically useful and provided valuable insights, our findings align with a growing body of scholarship arguing that formality and informality are not binary categories but overlapping and

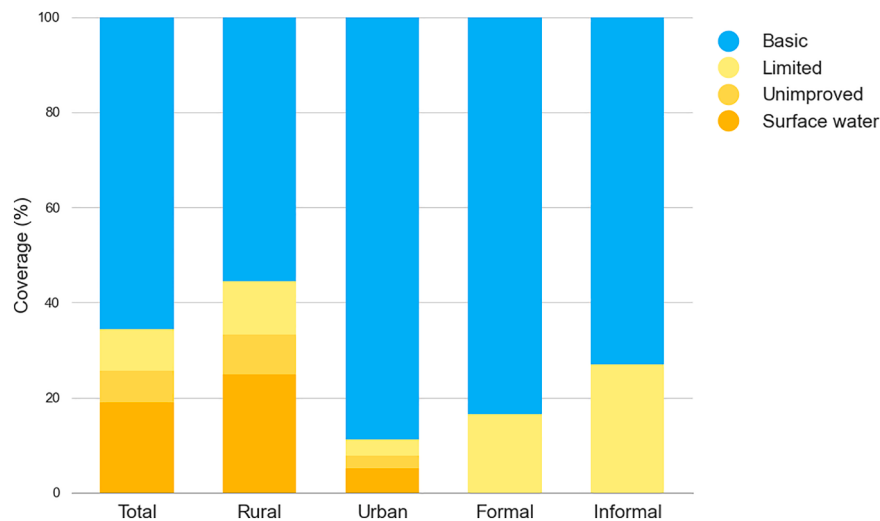


Fig. 3. Drinking water service levels in Kenya by settlement category. Bars show percentage coverage for total, rural, urban, formal, and informal urban settlement populations. Data for the total, rural, and urban Kenyan population (2024) were taken from the JMP WASH Data Portal (<https://washdata.org/data/household>). Coverage for formal and informal urban settlements is based on household survey data collected in March–May 2025 in Jericho Lumumba and Harambee ($n = 177$) and Korogocho ($n = 368$). Service levels follow JMP definitions.

intertwined modes of urban development that always and everywhere coexist in everyday practices, with formal settlements containing informal arrangements and vice versa (Dovey and Kamalipour, 2017; Jenkins and Eskemose, 2011; Smart and Koster, 2024). Infrastructural hybridity emphasises how different supply modes and governance arrangements intertwine in residents' ongoing negotiations to access and preserve water services (Jambadu et al., 2024). Our findings reveal three ways in which informal and formal practices overlap in everyday water access and infrastructure management.

Even in formal settlements, some households accessed formal water infrastructure informally – by removing meters, illegally connecting to pipes, or installing pumps to secure sufficient water – when structural inequalities in network design produce uneven, insufficient, unreliable, or unaffordable supply. Research from Mumbai similarly shows that residents navigate multiple institutional and material entry points – such as engaging municipal officials, plumbers, local politicians, or accessing leaking pipes – to secure water when formal provision is insufficient. What should be a universal public service becomes contingent on private means and social connections (Anand, 2017). From a HRTW perspective, such informalisation signals shortcomings in accessibility, availability, affordability, and equity, shifting responsibility for water access onto households rather than ensuring equal and reliable service (Swyngedouw, 2004).

Hybrid water access and informal coping strategies – including water storage, household rationing, and multiple household water sources – were widespread even in formal settlements with piped connections, mirroring practices commonly associated with informal settlements. In the Global South, residents often fill gaps in fragmented networks and unreliable centralised supply through hybrid arrangements combining informal and formal practices (Chatterjee and Kundu, 2022; Moretto et al., 2023) that combine formal infrastructure, market actors, and socially negotiated connections (Anand, 2017). Although such arrangements can enhance short-term access, they often reproduce inequalities, leaving service quality dependent on local capacity, social negotiation, and financial means rather than guaranteed state provision (Chatterjee and Kundu, 2022; Jambadu et al., 2024; Moretto et al., 2023). Studies from Bolivia (Wutich et al., 2016) and Nairobi (Chumo et al., 2025; Roaf et al., 2020; Social Justice Centres Working Group, 2020) show that informal practices can fill formal supply gaps, but may reproduce uneven service or price burdens where regulation and government oversight is weak. Integrating water vendors into governance and fostering active collaboration between vendors, residents, and

authorities is therefore essential for ensuring equitable, affordable, reliable, and high-quality water provision (Chumo et al., 2025), while recognising local management practices and community concerns (Walnycki, 2015).

Hybrid, community-led maintenance of water infrastructure was reported where government action was lacking, with formal settlement residents describing how they advocated for and contributed to repairs. In fragmented systems with mixed formal and informal, public and private connections, these hybrid approaches – which integrate diverse repair systems, actor expertise, and knowledge – are essential for maintaining service. As shown also in case studies from Accra, Ghana (Jambadu et al., 2024), maintenance and repair rely on collaborative arrangements between public engineers, private plumbers, and households, combining informal and formal practices and actors to keep supply functioning. Residents thereby become active participants in infrastructure maintenance rather than passive recipients. From a human rights perspective, such arrangements risk weakening state accountability, shifting responsibility for safe and reliable water onto communities, and producing uneven, contested outcomes that may exclude the most vulnerable (Chatterjee and Kundu, 2022; Moretto et al., 2023).

These findings highlight that water insecurity is not limited to informal settlements; even formal, middle-income settlements, that are often overlooked in research and practice, experience deteriorating and fragmented service. Responsibility for maintaining water access increasingly falls on property owners, water vendors, and household members, reinforcing infrastructural inequalities. Across settlement types, households rely on individualised coping strategies which are essential for managing water insecurity but do not address systemic inequities (Kasper et al., 2025). Hybrid co-production of water access and infrastructure maintenance needs to be better understood in terms of its potential to enable equitable and long-term service delivery, rather than transferring state responsibilities to disadvantaged communities (Moretto et al., 2023), especially as such arrangements are shaped by unequal power relations and do not inherently produce inclusive partnerships (Chatterjee and Kundu, 2022). Whether hybrid co-production mitigates or reinforces inequality depends on how municipalities, utilities, and residents share information, negotiate decisions, and allocate responsibilities in practice. Framing participatory planning as a form of “decision-support infrastructure” draws attention to how these interactions can be structured to reduce service blind spots and better connect technical provision with community needs (Gupta et al., 2025:

6). Interventions should target neighbourhood-specific needs within broader citywide plans. Such strategies may involve decentralised and heterogeneous supply systems including multiple actors, but must ultimately ensure sufficient, reliable, affordable, acceptable, and safe water for all residents (Kasper et al., 2025).

4.5. Methodological discussions and limitations

This study provides a comparative analysis of water insecurity in Nairobi's informal and formal settlements, exploring factors contributing to water insecurity, residents' perceptions, lived experiences, and coping strategies. Data collection combined FGDs and a household survey, building on advantages of both methods. FGDs captured multiple perspectives, dynamics, and emotions, enabling joint filling of knowledge gaps related to water insecurity (Anthonj et al., 2025b) and yielding more in-depth findings than traditional interviews alone.

Some FGDs may have exhibited typical group dynamics, such as dominant speakers or distractions, but these were mitigated through careful moderation (Anthonj et al., 2025b). Building on previous research on water insecurity in Global South contexts and informal settlements, we reduced social desirability, recall, and reporting bias by triangulating qualitative and quantitative data (Adams, 2018b, 2018a; Adams and Boateng, 2018). Although FGD data were rich and deeply grounded in participants' lived experiences, expectations of external aid or interventions may have influenced participants to emphasise challenges over existing community initiatives. Water quality was assessed through user perceptions rather than direct measurements, limiting contamination assessment but offering valuable insight into how residents experience water safety and quality. While some nuances may have been lost in translation, the study design and training devoted substantial effort to piloting, improving, (re-)translating, and adapting water insecurity and lived experiences concepts beyond technical and biomedical terminology to the multicultural context of Kenya – with support from local partners and research assistants experienced in working within both informal and formal settlements.

The household survey focused on households' main water sources, consistent with common global monitoring approaches (UNICEF and WHO, 2018). Improved indicators and survey tools are needed to better capture seasonal variation, differentiated uses, and combinations of sources, giving decision-makers detailed insights into household water management and community-level resilience to water insecurity (Anthonj and Brocklehurst, 2019; Elliott et al., 2017). Importantly, integrating FGDs enabled us to capture the dynamic use of multiple sources across seasons and purposes. This mixed-methods design revealed the complex water “portfolios” households rely on (Anthonj and Brocklehurst, 2019: 2), which are often overlooked when only a primary source is recorded. Better understanding multiple source use is essential for understanding everyday water management, health implications, and climate resilience, and for informing interventions that complement rather than substitute established practices (Anthonj and Brocklehurst, 2019; Elliott et al., 2017).

A major strength of this study on water insecurity experiences lies in its comparative elements. Comparative analysis across settlements, genders, and age groups was supported by Community Health Promoters at the village level, which helped reduce mistrust and power imbalance between interviewers and participants but may have introduced selection bias if CHPs guided us to households they knew. Although the cross-sectional design reflects experiences at one point in time, participants of different ages provided meaningful insights into seasonal patterns and changes in water insecurity over time. Our analysis differentiated only between women and men, which may have overlooked how water insecurity affects people across diverse gender identities, including transgender, non-binary, and other gender and sexual minorities. Broadening the conceptualisation of gender in water insecurity research could enhance understanding of differential impacts, improve data collection, and support more inclusive and equitable

interventions (Brewis et al., 2024). Complementary quantitative tools such as the Household Water Insecurity Experiences (HWISE) scale (Jepson et al., 2021) could further strengthen comparative analyses by systematically capturing material and psychosocial dimensions of water insecurity across contexts. A deeper analysis of these interlinked experiences, including their implications for health, well-being, and productivity, is beyond the scope of this paper and will be explored in future work (Box 1).

5. Conclusions

This mixed-methods study provides a novel, comparative assessment of the HRTW in Nairobi, offering gender- and age-sensitive insights into water insecurity and associated lived experiences across informal and formal settlements. First, the HRTW remains unmet across settlement types. Residents face frequent interruptions, unreliable supply, uneven access, long collection times, rising costs during shortages, and poor water quality, especially after service disruptions and in the rainy season. Seasonal fluctuations intensify insecurity, with rationing common in dry periods and contamination from flooding and sewer overflows during wet seasons. Second, residents adopt diverse coping strategies including alternative water sources, storage, and water treatment. Informal settlements remain more constrained by limited space and storage capacity, relying heavily on social networks, whereas formal settlements benefit from greater storage capacity through communal and household-level water tanks. Third, water insecurity is deeply gendered. Women in informal settlements bear the greatest burdens in terms of time, safety risks, and physical and emotional strain. Women more frequently reported challenges related to accessibility, water quality and safety, acceptability, and affordability, whereas men emphasised accountability issues linked to shortages, service interruptions, and poor water quality. Age differences were less pronounced. Finally, the comparative mixed-methods design underscores the value of analysing informal and formal settlements together through qualitative and quantitative approaches to identify shared and divergent challenges, providing critical evidence for targeted, context-sensitive interventions.

Our Nairobi case exemplifies the multidimensional and intersectional challenges of HRTW realisation in formal and, particularly, informal settlements. Water insecurity is shaped by socio-economic inequality, gendered labour and health burdens, reliance on informal services, and political marginalisation. Addressing these inequalities requires integrated approaches that combine infrastructure expansion, affordability, social equity, and meaningful participation to protect health, dignity, and equality for all residents. Moving toward the HRTW demands inclusive water governance, co-production partnerships, adaptive planning, and procedural freedoms that enable residents' active participation in decision-making (Gimelli et al., 2018; Rodrigues et al., 2024; Walnycki, 2015).

Despite diverse coping strategies, there remains a clear need to improve access to sufficient, safe, affordable, and acceptable water, particularly for vulnerable residents, as extreme weather events, including flooding, become more frequent. Household-level or plot-level distribution network expansion and upgrading would enhance accessibility, reduce contamination risks during collection and transport, and enable more flexibility in fetching water. Achieving this requires continuous collaboration between providers, authorities, and communities in informal and formal settlements to co-develop context-specific solutions that combine infrastructure improvements, behaviour-change initiatives, awareness raising campaigns, and participatory, community-based water governance. Leveraging local knowledge and practices through inclusive policies can empower residents, especially vulnerable groups, to manage water resources, maintain water quality, and sustain community-driven actions.

Key barriers persist, including land tenure in informal settlements – as residents often lack the proof of land ownership or authorisation

necessary for household tap connections – as well as institutional and financial barriers. The NCWSC's mandate currently limits provision to cluster chambers, leaving customers responsible for connections beyond this point. Expanding this mandate, alongside greater financial resources could support more equitable service delivery. Ultimately, implementing effective, equitable, and sustainable solutions requires active engagement between water providers, government authorities, and communities, alongside policy revisions to address structural barriers and promote gender-inclusive water governance that prioritises the experiences and needs of the most vulnerable populations.

Future studies could expand comparative analyses to additional informal and formal settlements in Nairobi and across regional and cultural contexts, including mixed or gradient settlement types. Our findings from Korogocho are largely transferable to other Nairobi informal settlements with similar NCWSC infrastructure, though Korogocho has relatively improved water supply compared to the most deprived slums, where households rely more on kiosks and communal points than in-dwelling or yard connections. Similarly, our findings from Jericho and Harambee are generalisable to other areas served by NCWSC infrastructure but may differ from more affluent estates. Spatial analyses could reveal inequities in WASH access within and across settlements, pinpointing populations most in need of targeted support (Kim et al., 2022). Participatory methods, such as go-along interviews, in-depth interviews, photovoice, or co-design workshops, are needed to engage residents, particularly vulnerable and marginalised groups, in co-producing knowledge and practical solutions (Corburn and Karanja, 2016; Karuga et al., 2023; Saunders et al., 2016). Complementary studies on risk perception, water-handling behaviours, and effectiveness of awareness-raising campaigns can support interventions addressing both contamination risks and social practices. Future theoretical work could develop a conceptual integration of the Human Right to Water and household water insecurity frameworks that more systematically links normative standards with lived experiences of water insecurity. Building on this study, future work will examine the effects of water insecurity on well-being and productivity, as well as residents' preferences and willingness to pay for improved water infrastructure in informal settlements, to inform context-sensitive interventions.

Ethics in publishing statement

I testify on behalf of all co-authors that our article submitted followed ethical principles in publishing.

Title: Water insecurity and lived experiences in Nairobi, Kenya: a comparative mixed-methods study of formal and informal settlements through the lens of the Human Right to Water

All authors agree that:

This research presents an accurate account of the work performed, all data presented are accurate and methodologies detailed enough to permit others to replicate the work.

This manuscript represents entirely original works and or if work and/or words of others have been used, that this has been appropriately cited or quoted and permission has been obtained where necessary.

This material has not been published in whole or in part elsewhere.

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All authors have been personally and actively involved in substantive work leading to the manuscript and will hold themselves jointly and individually responsible for its content.

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Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work, the authors used ChatGPT in order to improve the readability and language of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

CRediT authorship contribution statement

Julia Foellmer: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis. **Dennis Musyoka:** Writing – review & editing, Methodology, Investigation, Data curation, Conceptualization. **Dancan Owaga:** Writing – review & editing, Investigation. **Caroline Kabaria:** Writing – review & editing, Project administration. **Paula Janeka:** Visualization. **Carmen Anthonj:** Writing – original draft, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

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